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An Automatic Chlorination System for Eliminating Biological Growth in Pumping Systems for Automatic Instrumentation

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AN AUTOMATIC CHLORINATION SYSTEM FOR ELIMINATING BIOLOGICAL GROWTH IN PUMPING SYSTEMS FOR AUTOMATIC INSTRUMENTATION

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AN AUTOMATIC CHLORINATION SYSTEM FOR ELIMINATING BIOLOGICAL GROWTH IN PUMPING SYSTEMS FOR AUTOMATIC INSTRUMENTATION

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FOREWORD

Environmental measurements are required to determine the quality of ambient waters and the character of waste effluents. The Environmental Monitoring and Support Laboratory - Cincinnati conducts research to:

> Develop and evaluate techniques to measure the presence and concentration of physical, chemical, and radiological pollutants in water, wastewater, bottom sediments, and solid waste.
>
> Investigate methods for the concentration, recovery, and identification of viruses, bacteria and other microbiological organisms in water. Conducts studies to determine the responses of aquatic organisms to water quality.
>
> Conduct an Agency-wide quality assurance program to assure standardization and quality control of systems for monitoring water and wastewater.

The Instrumentation Development Branch, EMSL, investigates the performance of instrumentation and the requirements for the collection and storage of representative waste samples. In this study, an automatic chlorination system for the elimination of biological growths in a sampling system has been evaluated.

Dwight G. Ballinger
Director
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ABSTRACT

Automatic chlorination was determined to be satisfactory for elimination of microbial growth (slime) in monitor pumping systems. With chlorination, changes in dissolved oxygen levels through the sampling system were minimized. Optimum chlorine concentration and frequency of chlorine addition to the system were determined during the period of maximum biological activity.

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SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

- This investigation has shown that automatic chlorination is an effective method for eliminating microbial growth (slime) from the inner pipeline surfaces of pumping systems for automatic instrumentation.

- A gaseous chlorine feed rate of at least 2 to 2-1/2 pounds per day, added to the system once a day for 10 minutes was the minimum quantity of chlorine required to keep the dissolved oxygen (DO)-change caused by microbial metabolism, minimal. Total flow rate through this system was 18 gpm and during chlorination one-half of this was diverted through the chlorinator and then recirculated. A chlorine feed rate of 2 pounds per day gives a peak calculated concentration of 18.51 mg/l. Sample analysis revealed that there was 9.6 and 10.4 mg/l of free and total residual chlorine respectively within the system when it was approximately one-half charged. DO samples that were collected, across the pumping system, 23 hours after this chlorination cycle gave an average DO-change of zero. This average was made up of 5 DO-change readings that ranged from -0.05 to +0.05 mg/l. These tests were made during the warm weather periods of July and August when microbial growth was at a maximum.

- The average, of 10 DO-change readings across the system before any application of chlorine, was 0.28 mg/l with a range of 0 to 0.5 mg/l.

- Settled sludge within the inlet strainer will cause high and erratic DO-change readings.

- This system had a flow rate of 18 gpm and incorporated 200 feet of 1-1/4 inch ID and 300 feet of 1-1/2 inch ID line. Therefore sample velocities were 4.71 and 3.26 feet per second respectively.

- It is recommended first, that pumping systems be designed with a high velocity of flow (greater than 4.7 ft/sec) for minimal sample degradation. They should be straight-through systems with no enlarged sections where sludge can settle. Pipelines should be made of high density material that minimize the small cavities where microbial growth can get started and pipeline length should be kept as short as possible. Inlet strainers should be easily accessible so that they can be cleaned frequently, thus eliminating sludge build-up.

- Need for automatic chlorination can be determined by testing for DO loss across the system during the warm months.

- In my opinion, automatic chlorination is probably not required for properly designed systems during cold weather when biological metabolism is slow. Chlorination may not be required during warm weather for properly designed systems on streams where pollution is light. It may be that there is a sample velocity, within a properly designed system, above which sample degradation would be insignificant. If there is such a velocity, then the system should be designed for same, hence eliminating the need for automatic chlorination. More research is needed in this area to determine this velocity for specific line lengths and degrees of sample pollution.

- If it is determined that automatic chlorination is required, after proper system design, then this study has shown that chlorination at low concentration is a satisfactory method for minimizing sample change that results from microbial growth within the pumping system.

SECTION 2

INTRODUCTION

A pumping system that delivers raw water sample flow to automatic instrumentation should be designed for minimum sample change. Stierli (1) discussed the importance of high sample velocity for minimal DO change. Lauch (2) explains that sample change does occur in a system that allows low velocity of flow and settling. Lauch (3) discusses intake system design for minimal sample change.

In a properly designed system, slime bacteria may still grow on the inner pipe surfaces and cause sample change when polluted water is pumped through long lines during warm weather periods. The severity of this change may or may not be significant enough to warrant automatic cleaning. This report describes the design and evaluation of an automatic system that periodically chlorinates the lines to remove slime microbes. The system was evaluated during cold and warm weather to determine the optimum quantity and frequency of chlorination. This evaluation was performed at a field test station on the Little Miami River at Cincinnati, Ohio.

DO was the parameter used to determine sample change within the pumping system. DO is an obvious parameter to use because it is easily and accurately measured; however, since a decrease in DO results from microbial metabolism, it must be noted that other less conspicuous parameters may be changing as well.

SECTION 3

DESCRIPTION OF SYSTEM

A complete parts list for this chlorination system is given in the Appendix. Figure 1 depicts a flow diagram of the system with inset illustrating a typical valve cycle. The total flow through the chlorination system was 18 gpm. The manifold shown within the dotted lines is located inside the instrumentation shelter. V_1, V_2, and V_3 are automatic valves. Flow control valves (FCV) were used to balance the system. The first stage pump was submerged in the river, and the second stage pump was located between the river and shelter. The total length of sample line between the river and shelter was approximately 500 feet (91.44 m). Refer to Figure 1 for an explanation of a typical valve cycle:

> Normally V_1 is closed and sample flow is from the river to the monitor. When chlorination is required, V_1 opens and 1 minute later V_2 closes; the lag eliminates the possibility of restricting positive-displacement pumps. With V_2 closed, half of the flow is to the monitor and the other half (9 gpm) goes through V_1. After V_1 the flow divides with 4 gpm going through the ejector to develop a negative pressure at V_3 and 5 gpm mixing with the ejector effluent for greater dilution of Cl_2. When the return side of the system is stabilized (air eliminated), V_3 opens and chlorine gas is drawn into the system. The resulting chlorinated water flows to the inlet of the first stage pump, and after 10 minutes of chlorination V_3 closes. The system flushes with non-chlorinated water for 18.6 minutes, V_2 opens, and 1 minute later V_1 closes; the cycle is completed.

The valve cycle was controlled by the timing circuit shown in Figure 2 and the following is a sequential explanation of events that were controlled by this circuit:

1. S_5 closes according to the setting of the 24-hour timer. S_6 (power relay) closes and valve V_1 opens. The magnet (MAG) is energized through the delay; S_7 closes and powers the motor (M) of the cam timer. The delay coil de-energizes and magnet power is off.

2. S_2 closes and powers V_2, hence V_2 closes.

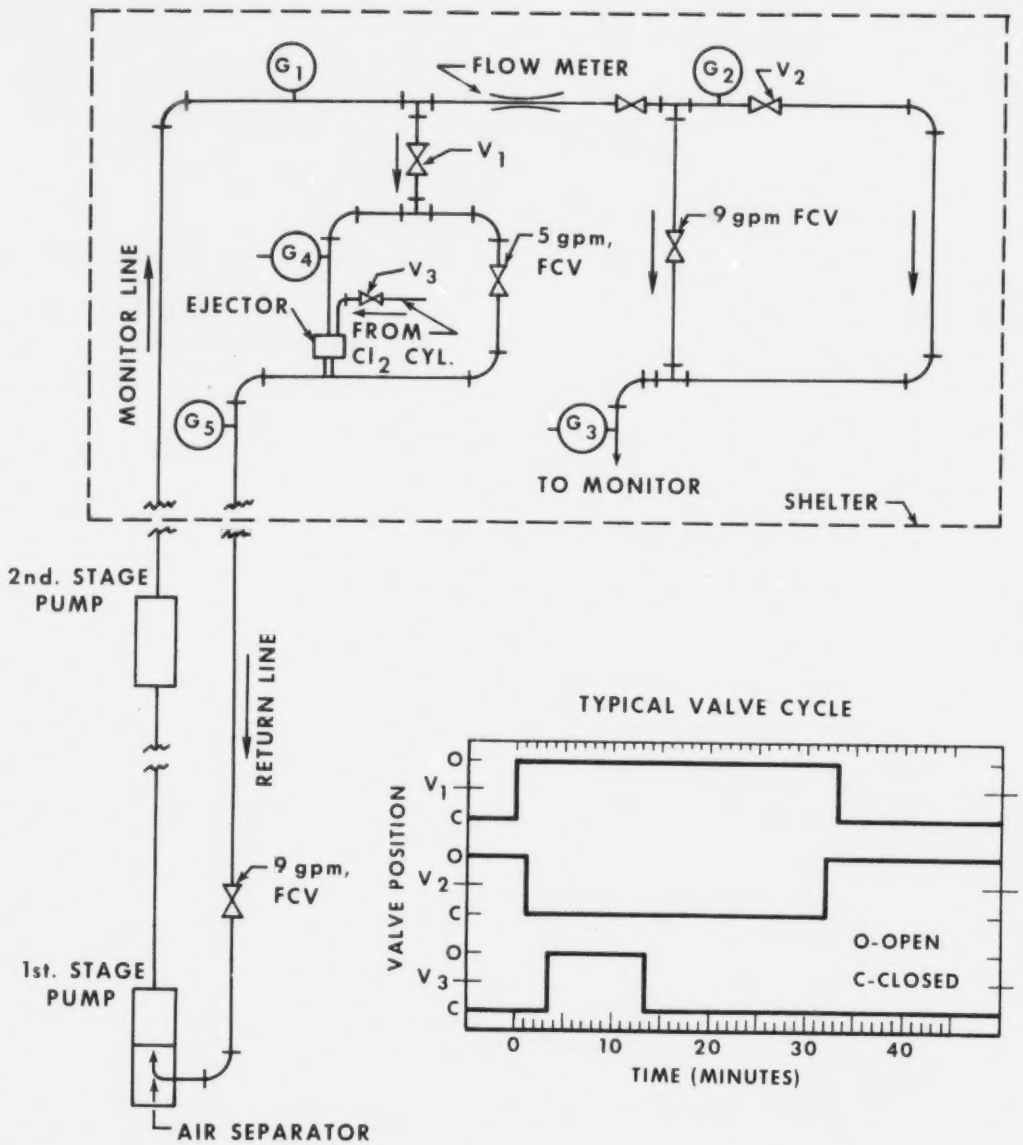

Figure 1. Flow diagram

3. S_3 closes, the interval timer starts and solenoid valve V_3 opens for a precise period of time.

4. The interval timer closes V_3.

5. S_4 changes position and V_2 opens.

6. S_1 changes position and V_1 closes. This completes the valve cycle.

7. S_5 opens, hence S_6 opens.

8. S_7 opens after 1 hour has elapsed.

Note that the cam timer was set up to eliminate all backlash. The interval timer is a precision device and therefore it was used to control V_3 and allow Cl_2 to enter the system for an exact period of time. Since one of the purposes of these tests was to determine the quantity and frequency of chlorination, an accurate and precise control function was required. For routine intake cleaning a combination of the 24-hour timer and the cam timer would suffice (eliminating the interval timer). It may also be possible to use a signal from the instrumentation to start a cam timer and this would eliminate the 24-hour timer.

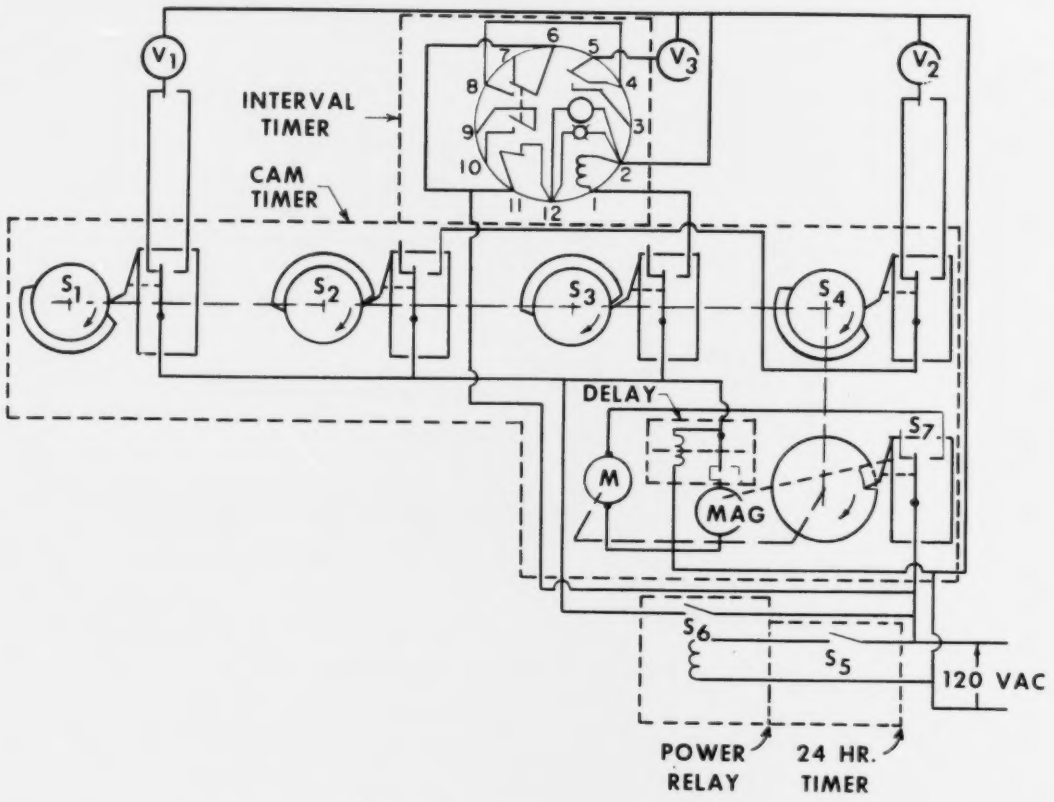

Figure 2. Timing circuit.

The cylinder of chlorine gas was located in a small shelter that was separated from the main instrumentation shelter (Figure 3). The chlorinator was attached directly to the top of this cylinder and included a flowmeter with needle valve for setting chlorine flow rate. This type of chlorinator supplies chlorine gas to the system only when a negative pressure is developed by pressurized water flowing through the ejector. If water flow stops because of pump failure, chlorine flow will also stop. This is an excellent safety precaution. Chlorinator ejector combinations of this type are commercially available from a number of manufacturers. One objective of these tests was to show that a very small quantity of chlorine is sufficient to eliminate slime growth in the lines. For example, if a chlorine feed rate of 2 pounds per day added to the system for 10 minutes, once a day during the 6-warm weather months is sufficient to eliminate slime bacteria, then a small 15-pound cylinder of chlorine would last longer than 5 years.

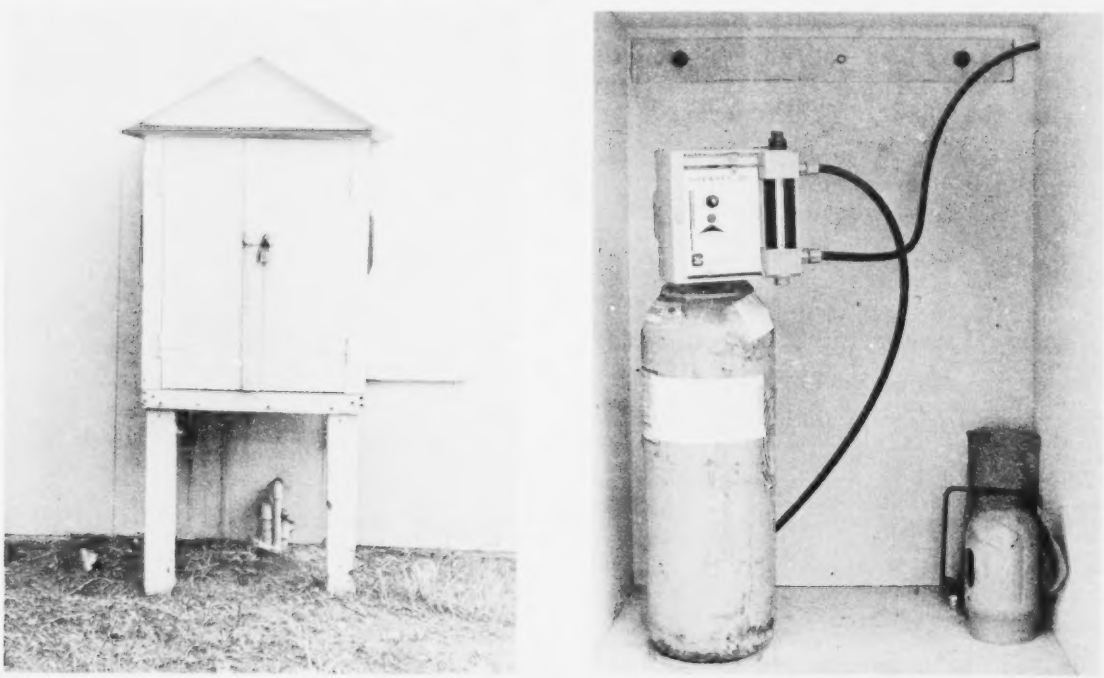

Figure 3. Chlorine shelter.

SECTION 4

COMPUTATION OF CHLORINE CONCENTRATION AND METHODS OF SAMPLE ANALYSIS

During chlorination half of the flow goes through V_1, is chlorinated at the ejector, and then returns to the pump inlet (Figure 1). The other half flows into the monitor and then to waste. Half of the flow entering the pump inlet is chlorinated and the other half is new river water. Assume that the initial chlorine concentration in the return line immediately after the ejector is C. When this concentration enters the first stage pump inlet, the new concentration in the monitor line is approximately C/2. When C/2 reaches the ejector, the new concentration in the return line is approximately C + C/2. The concentration of C + C/2 again enters the pump inlet, is diluted in half and becomes (C + C/2)/2. The following equations give the chlorine concentration below and above the ejector.

$$\text{Below ejector, concentration} = C \sum_{n_i=1}^{n} 1 + (1/2)^{n_i} \approx 2C \qquad (1)$$

$$\text{Above ejector, concentration} = C \sum_{n_i=1}^{n} (1/2)^{n_i} \approx C \qquad (2)$$

where

C = the initial concentration just after ejector

n = number of complete cycles

$$n = \frac{\text{elapsed time}}{\text{residence time of system}}$$

Also: n is an integer so that only completed cycles are employed
residence time of return line = approximately 2.6 minutes
residence time of monitor line = approximately 2.1 minutes
residence time of system = approximately 4.7 minutes.

Note that the concentration within the return line approaches 2C, and the concentration in the monitor line approaches C. After three cycles (approximately 14.1 minutes), the concentration in the monitor line at V_1 is 0.875C (equation 2). Therefore, it takes a few cycles for the monitor line to build up to maximum concentration; it is also necessary to leave

the return line flush for a period of time with V_3 closed to remove all chlorine from the system.

METHOD OF SAMPLE ANALYSIS:

DO - Azide Modification of the Winkler Method (4)
Chlorine - DPD Ferrous Titrimetric Method (4)
Temperature - Matheson Thermometer, Catalog No. 62109-10
1 to 51C. Division 1/10C.
pH - Instrumentation Laboratory, Inc. pH/mV Electrometer Model 245.

SECTION 5

RESULTS

After initial installation, the system was checked during cold weather and baseline information was obtained. The system was then tested during warm weather to determine minimum concentration and frequency of chlorination during the period of maximum biological activity.

COLD WEATHER TESTS

These tests were run at chlorine feed rates of 1 pound per day and 1/2 pound per day. Samples were taken from the monitor line inside the shelter (Figure 1). Table 1 shows that after 8.6 minutes of chlorination, the median total chlorine residuals were 4.1 mg/l and 2.3 mg/l at feed rates of 1 pound per day and 1/2 pound per day respectively. This compares to values, that were calculated and applied to equation 2, of 4.6 and 2.3 mg/l and shows that substantially all of the chlorine added was recirculating. Table 1 illustrates that free chlorine residual was a substantial part of the total chlorine residual and that addition of chlorine lowered the pH of the water slightly. Lowered pH is desirable because the hypochlorous acid (HOCl) component of the free residual is the chlorine species that is most effective for killing microbes and this species becomes more predominent as pH decreases (5).

WARM WEATHER TESTS

Warm weather tests were performed from July 11 through August 11, 1972, to determine the optimum quantity of chlorine and frequency of chlorine addition for this system during the period of maximum biological activity. Results are as follows:

7/11/72

The system had been running continuously for 2 weeks prior to this date without chlorination. Tests were performed this day to obtain background information without the addition of chlorine. A sample for DO was taken at the river inlet and inside the shelter, from the monitor manifold, approximately every 1/2 hour throughout the day. The shelter sample was taken approximately 3 minutes after the river sample to allow for residence time. Differences in DO between the river and the shelter are given in Table 2. Average DO-change across the system this day was 0.28 mg/l. Two erratic DO readings after a heavy rain shower were not included in this average because these

Table 1. COLD WEATHER DATA*
12/1/71

	Time	Measured chlorine concentration (mg/l) free residual	total residual	pH shelter	Temp C°	DO (mg/l) river	shelter
Chlorine Feed Rate = 1 lb./day	10:20†						
	10:32	3.0	4.0	7.6	7.0		
	10:50	0.0	0.7	8.0	7.0		
	11:00	0.0	0.0	8.0	5.3		
	11:20†						
	11:32	3.1	4.2	7.4	6.8		
	11:50	0.0	0.5	7.8	6.2		
	12:00	0.0	0.0	7.9	5.6		
	1:00†						
	1:12	3.1	4.1	7.4	6.7		
	1:30	0.0	0.7	7.8	6.5		
	1:40	0.0	0.0	7.9	5.8		
Chlorine Feed Rate = 0.5 lb./day	2:10†						
	2:22	1.7	2.8	7.5	6.5		
	2:40	0.0	0.2	7.8	6.7		
	2:50	0.0	0.0	7.9	5.4		
	3:05					12.7	12.90
	3:20†						
	3:32	1.2	2.3	7.4	6.1		
	3:50	0.0	0.2	7.9	6.1		
	4:00	0.0	0.0	8.0	5.3		
	4:15					12.7	12.75
	4:20†						
	4:32	1.0	2.2	7.5	6.3		
	4:50	0.0	0.5	7.8	5.9		
	5:00	0.0	0.0	8.0	5.0		

*Cl_2 valve V_3 opens 3.4 minutes after cycle starts
Cl_2 added for 10 minutes
Total length of cycle = 33 minutes.

†Start of chlorination cycle.

readings probably resulted from an abnormal stirring up of a sludge deposit inside of the inlet strainer. It is also possible that the increased DO-change was caused by the pipeline slime microbes metabolizing a higher substrate concentration that was washed into the stream during the shower.

Table 2. BACKGROUND DATA BEFORE CHLORINATION
7/11/72

Time	DO (mg/1) river	DO (mg/1) shelter	DO change (mg/1)	Temperature °C river	Temperature °C shelter	Remarks
9:45a.m.	8.95	8.70	-0.25	23.1	23.0	
10:30	9.10	8.70	-0.40	23.1	23.0	
11:00	9.20	8.70	-0.50	23.6	23.1	
11:30	9.05	8.80	-0.25	23.4	23.1	
12:00N	9.20	8.95	-0.25	23.5	23.2	
12:30p.m.	9.35	9.05	-0.30	23.4	23.2	
1:00	9.30	9.10	-0.20	23.2	23.2	
2:30	10.20	10.00	-0.20	23.6	23.8	
3:00	10.60	10.60	0.00	24.1	24.0	
3:30	9.90	7.45	-	24.2	23.8	Heavy shower
4:00	9.80	8.65	-	24.4	24.1	
5:05	7.80	7.40	-0.40	24.6	24.6	
		Average DO =	-0.28			

8/11/72

The data for this final day of testing are shown in Table 3. Prior to and during these tests, chlorine was being added to the system at a rate of 3 pounds per day for 10 minutes three times a day. The inlet strainer was cleaned three times between 7/11 and 8/11/72. The average DO change on 8/11/72 was 0 mg/1 before chlorination and 0.005 mg/1 after chlorination, which when compared with the average DO change on 7/11/72 shows that automatic chlorination along with inlet strainer cleaning is an effective method for decreasing sample change across the system.

7/12 through 8/11/72

The purpose of these tests was to determine the minimum quantity and frequency of chlorine required for effective cleaning of this specific system during the period of maximum biological activity. Data for these tests are included in Table 3 and Tables 4 through 12 of the Appendix. During these tests the number of chlorine cycles per day were increased as follows:

Table 3. FINAL DAYS TESTING AFTER CHLORINATION
8/11/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
9:00a.m.	9.25	9.30	0.05	20.9	21.2			
9:15	9.40	9.35	-0.05	20.7	21.3			
9:30	9.70	9.55	-0.15	20.7	21.4			
9:45	9.95	10.10	0.15	21.0	21.6			
10:00	Start Cl_2 cycle, rate = 3#day, cycles/day = 3							
10:06						7.16	0.0	0.0
10:11						7.18	10.0	11.2
10:16						6.70	17.6	21.2
10:21						6.95	8.8	8.8
10:26						6.98	2.9	3.4
10:33						7.24	0.9	1.3
10:43						7.51	0.0	0.0
11:00	10.80	10.85	0.05		22.4			
11:15	11.00	11.05	0.05		22.5			
11:30	11.20	11.10	-0.10					
11:45	11.50	11.40	-0.10					
12:25p.m.	12.15	12.15	0.00		23.2			
12:40	12.70	12.80	0.10		23.4			
2:00	14.40	14.55	0.15		24.2			
2:30	14.60	14.70	0.10		24.4			
3:00	15.20	15.35	0.15		24.5			
3:30	16.00	15.95	-0.05		24.7			
4:00	16.50	16.10	-0.40		24.7			
		Average =	0.005					

Once a day at 10:00 a.m.
Twice a day at 10:00 a.m. and 10:00 p.m.
Three times a day, 10:00 a.m., 6:00 p.m., and 2:00 a.m.

Five DO samples were taken across the system approximately 15 minutes apart, before and after the 10:00 a.m. chlorination cycle. During a chlorination cycle, readings for free and total chlorine residuals along with pH were taken initially, approximately at peak concentration, at the end of the cycle, and 10 minutes after the end of the cycle.

The DO-change data from Tables 4 through 9 (Appendix) are summarized in Figures 4 and 5. Figure 4 shows data just after the chlorination cycle ends and Figure 5 displays data 23 hours after a chlorine cycle ended. The objective was to determine the chlorine concentration, in Figure 4, that gave minimum DO change (for chlorination once a day) and then start increasing the frequency of chlorination each day until the DO change just before the 10:00 a.m. cycle equaled zero. Figure 5 shows that an average DO change of zero was obtained when chlorine was added once a day at a feed rate of 2 pounds per day. The next day (after a feed rate of 2.5 pounds per day) the average DO change was 0.09 mg/l. The pumping system went off, for some unknown reason, the evening before these data were taken and this probably caused the slight increase in DO-change. Figure 4 shows that the average DO-change, immediately after chlorination, at chlorine feed rates of 2.5

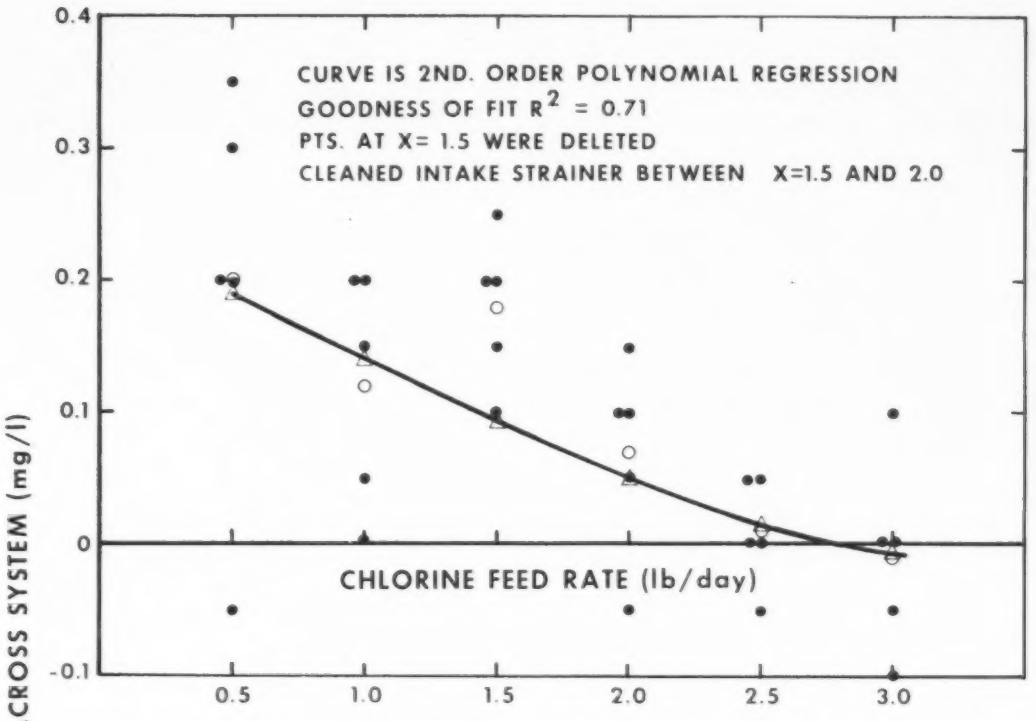

Figure 4. DO-Change immediately after chlorination at the feed rate shown

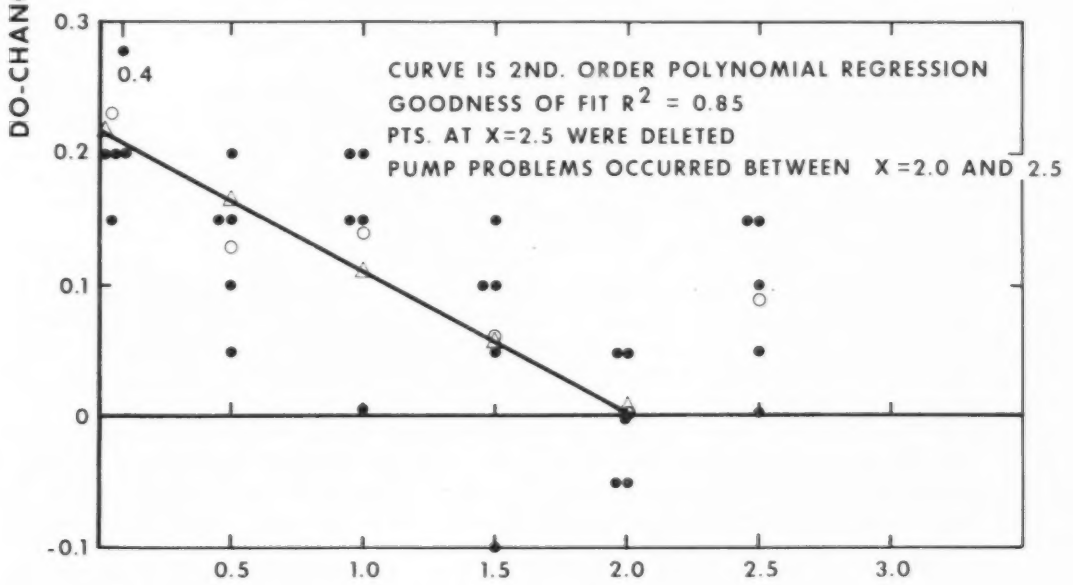

Figure 5. DO-Change 23 hrs. after chlorination at the feed rate shown

and 3 pounds per day were 0.01 and -0.01 mg/1 respectively (essentially zero). Therefore, these tests show that chlorine feed rates of at least 2 to 2.5 pounds per day, added to the system once per day was sufficient to keep biological growth and therefore DO-change minimal.

Testing was continued (Tables 3 and 10, 11, 12, Appendix) at chlorine feed rates of 2.5 and 3 pounds per day and 2 to 3 chlorination cycles per day with no additional significant reduction in DO-change. It was therefore concluded that a minimum chlorine feed rate of 2 to 2.5 pounds per day, added to the system once a day for 10 minutes was sufficient to keep this system free of biological growth, hence minimal DO-change. A chlorine feed rate of 2 pounds per day gives a peak calculated total residual concentration of 18.51 mg/1.

Figure 4 shows a step change in data points between feed rates of 1.5 and 2 pounds per day. The strainer was cleaned of sludge between these two settings and this is probably the reason for the step change

The second order polynomial regression curves (Figures 4 and 5) were calculated on a Tektronix 4051 using their Mathematics Plot 50 Tape, Volume 2. These calculated points are depicted by the triangles in the figures.

SECTION 6

PROBLEMS ENCOUNTERED, SOLUTIONS

Along with normal debugging, one significant problem was that of eliminating air from the return line at the start of a chlorination cycle. At this specific location there is about 40 feet of elevation between the river and the shelter. With V_1 closed (Figure 1) a considerable negative pressure developed in the return line, and both gauges G_4 and G_5 read lower than atmospheric. With V_1 open during a chlorination cycle, G_5 was still reading negative. At negative pressures dissolved gases will come out of solution, and also air can be sucked into the system. Initially, there was very little clearance between the exit from the return line and the inlet to the first stage pump. The air could not escape from the system and it kept recirculating and caused severe fluctuation in water flow.

Two modifications were made to eliminate the problem:

1. A 9-gpm flow control valve (FVC) was installed in the return line near the first stage pump to keep positive pressure in the return line during a chlorination cycle.

2. An air separator (Figure 6, Appendix) was installed at the exit of the return line just before the inlet to the first stage pump. The horizontally installed separator reduced the velocity of the return flow and allowed clearance before the pump inlet for air to escape. This separator was an in-house design that performed satisfactorily during these tests. Commercial air separators are also available.

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5. Fair, G. M., J. C. Geyer, and D. A. Okun. Water and Wastewater Engineering. Volume 2. John Wiley and Sons, New York, N.Y., 1968.

APPENDIX A

Table 4. CHLORINATION SYSTEM TESTS
7/12/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:30a.m.	7.35	6.95	-0.40	22.8	22.9			
8:45	7.15	7.00	-0.15	22.7	22.9			
9:00	7.15	6.95	-0.20	22.9	23.0			
9:15	7.20	7.00	-0.20	22.9	23.1			
9:30	7.10	6.90	-0.20	23.0	23.1			
		Average DO =	0.23					
10:00	Start Cl_2 cycle, rate = slightly > 0.5#/day, cycles/day = 1							
10:06						7.9	0.4	1.3
10:16						7.6	4.1	5.5
10:33						7.9	0.5	0.8
10:43						8.1	0.2	0.2
11:45	8.40	8.20	-0.20	23.9	23.8			
12:00N	8.65	8.30	-0.35	23.9	23.8			
12:15p.m.	8.60	8.65	0.05	24.2	24.0			
12:30	9.00	8.70	-0.30	24.2	24.1			
12:45	9.20	9.00	-0.20	24.4	24.3			
		Average DO =	0.20					

Table 5. CHLORINATION SYSTEM TESTS
7/13/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:30a.m.	7.50	7.35	-0.15	23.5	23.8			
8:45	7.50	7.45	-0.05	23.7	23.8			
9:00	7.35	7.25	-0.10	23.7	23.9			
9:15	7.55	7.40	-0.15	23.9	24.0			
9:30	7.60	7.40	-0.20	24.0	24.0			
		Average DO =	0.13					
10:00	Start Cl_2 cycle, rate = 1#/day							
10:06						7.95	0.0	0.3
10:16						7.53	7.2	8.1
10:33						7.83	0.4	1.0
10:40						7.92	0.0	0.0
11:00	8.20	8.20	0.00	24.8	24.7			
11:15	8.40	8.20	-0.20	24.8	24.7			
11:30	8.50	8.45	-0.05	24.9	24.9			
11:45	8.75	8.60	-0.15	25.1	25.0			
12:00N	9.00	8.80	-0.20	25.2	25.1			

Table 6. CHLORINATION SYSTEM TESTS
7/14/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:30a.m.	7.15	7.00	-0.15	24.6	24.6			
8:45	7.05	6.90	-0.15	24.6	24.7			
9:00	7.20	7.00	-0.20	24.6	24.7			
9:15	7.10	6.90	-0.20	24.7	24.8			
9:30	7.15	7.15	0.00	24.7	24.8			
		Average DO =	0.14					
10:00	Start Cl_2 cycle, rate = 1.5#/day, cycles/day = 1							
10:06						7.95	0.0	0.20
10:16						7.63	9.2	10.60
10:33						7.85	0.2	0.50
10:40						7.95	0.0	0.05
11:00	7.80	7.65	-0.15	25.3	25.3			
11:15	7.95	7.70	-0.25	25.4	25.4			
11:30	8.15	7.95	-0.20	25.4	25.4			
11:45	8.40	8.20	-0.20	25.7	25.6			
12:00N	8.40	8.30	-0.10	25.7	25.7			
		Average DO =	0.18					
				7/15/72				
10:00a.m.	Start Cl_2 cycle, rate = 1.5#/day, cycles/day = 1							
10:06						8.02	0.0	0.1
10:16						7.52	9.1	9.8
10:33						7.88	0.2	0.6
				7/16/72				
10:00a.m.	Start Cl_2 cycle, rate = 1.5#/day							
10:06						7.78	0.0	0.1
							9.3	10.2

Table 7. CHLORINATION SYSTEM TESTS
7/17/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
9:00a.m.	6.60	6.45	-0.15	23.4	23.5			
9:15	6.55	6.65	0.10	23.3	23.6			
9:30	6.65	6.55	-0.10	23.3	23.6			
9:45	6.65	6.55	-0.10	23.4	23.6			
10:00	6.80	6.75	-0.05	23.4	23.7			
		Average DO =	0.06					
10:00	Start Cl_2 cycle, rate = 2#/day, cycles/day = 1 Changed to 4#/day Cl_2 flow tube							
10:08							0.1	0.2
10:16							9.6	10.4
10:33								
10:40								
11:30	7.30	7.15	-0.15	23.7	23.8			
11:45	7.35	7.25	-0.10	23.7	23.9			
12:00N	7.55	7.60	0.05	24.1	24.3			
12:15	7.70	7.65	-0.05	24.4	24.4			
12:30	7.75	7.65	-0.10	24.4	24.4			
		Average DO =	0.07					

Table 8. CHLORINATION SYSTEM TESTS
7/18/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:50a.m.*	7.30	7.35	0.05	24.3	24.2			
9:00	7.40	7.35	-0.05	24.5	24.4			
9:15	7.35	7.30	-0.05	24.5	24.5			
9:25	7.45	7.50	0.05	24.6	24.6			
9:35	7.55	7.55	0.00	24.8	24.7			
		Average DO =	0.00					
10:00	Start Cl_2 cycle, rate = 2.5#/day, cycles/day = 1							
10:06						7.95	0.0	0.1
10:16						7.50	6.8	6.8
10:35						7.78	0.4	0.9
10:43						7.74	0.0	0.1
11:00	8.55	8.60	0.05	25.6	25.5			
11:15	8.70	8.65	-0.05	25.6	25.5			
11:25	8.85	8.85	0.00	25.7	25.7			
11:45	9.20	9.15	-0.05	26.1	26.1			
12:00	9.30	9.30	0.00	26.0	26.0			
		Average DO =	0.01					

*Low pressure switch turned system off at 10:00 p.m., 7/17/72; system turned back on at 8:30 a.m., 7/18/72.

Table 9. CHLORINATION SYSTEM TESTS
7/19/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:45a.m.*	7.85	7.75	-0.10	25.4	25.4			
9:00	7.95	7.95	0.00	25.6	25.6			
9:15	8.20	8.15	-0.05	25.6	25.6			
9:30	8.40	8.25	-0.15	25.8	25.8			
9:45	8.50	8.35	-0.15	25.9	25.8			
		Average DO =	0.09					
10:00	Start Cl_2 cycle, rate = 3#/day, cycles/day = 1							
10:06						8.10	0.0	0.2
10:16						7.49	7.0	7.5
10:33						7.98	0.3	0.7
10:39						8.09	0.2	0.2
10:45	9.55	9.45	-0.10	26.5	26.4			
11:00	9.75	9.85	0.10	26.5	26.5			
11:15	9.95	9.95	0.00	26.7	26.6			
11:30	10.10	10.10	0.00	26.8	26.8			
11:45	10.45	10.50	0.05	27.0	26.9			
		Average DO =	-0.01					
			7/20/72					
10:00a.m.*	Start Cl_2 cycle, rate = 3#/day, cycles/day = 1							
10:06						7.95	0.0	0.3
10:16						7.45	7.0	8.2
10:33						7.95	0.5	0.8

*Low pressure switch turned system off at 10:00p.m. the previous night, system burned back on at 8:30a.m.

Table 10. CHLORINATION SYSTEM TESTS
8/8/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:50a.m.	7.40	7.80	0.40	21.1	21.6			
9:05	7.25	7.30	0.05	21.0	21.6			
9:20	7.35	7.30	-0.05	21.1	21.5			
9:35	8.00	7.75	-0.05	21.2	21.7			
9:50	7.60	7.60	0.00	21.2	21.7			
		Average DO =	-0.07					
10:00	Start Cl_2 cycle, rate = 3#/day, cycles/day = 2							
10:06						7.10	0.0	0.2
10:16						6.81	22.6	22.6
10:33						7.01	1.5	1.5
10:43						7.00	0.0	0.0
11:10	8.15	8.10	-0.05	22.0	22.5			
11:25	8.20	8.20	0.00	22.2	22.6			
11:40	8.25	8.05	-0.20	22.2	22.7			
11:55	8.25	8.30	0.05	22.5	22.8			
12:10p.m.	8.40	8.40	0.00	22.8	23.0			
		Average DO =	0.04					
1:00	Cleaned first stage pump strainer							

Table 11. CHLORINATION SYSTEM TESTS
8/9/72

Time	DO (mg/l) river	DO (mg/l) shelter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:30a.m.	7:30	7.30	0.00	20.8	21.5			
8:45	7.30	7.30	0.00	20.8	21.5			
9:00	7.45	7.40	-0.05	21.1	21.5			
9:15	7.45	7.45	0.00	20.9	21.6			
9:30	7.65	7.45	-0.20	20.8	21.6			
		Average DO =	0.05					
10:00	Start Cl_2 cycle, rate = 2.5#/day, cycles/day = 2							
10:06						7.06	0.0	0.0
10:16						6.80	14.6	14.6
10:33						7.03	0.3	0.5
10:43						7.00	0.0	0.0
11:00	8.15	8.05	-0.10	21.3	21.9			
11:15	8.15	8.10	-0.05	21.3	22.0			
11:30	8.30	8.20	-0.10	21.3	21.9			
11:45	8.30	8.25	-0.05	21.3	22.0			
12:00N	8.55	8.50	-0.05	21.9	22.1			
		Average DO =	0.07					

Table 12. CHLORINATION SYSTEM TESTS
8/10/72

Time	DO (mg/l) river	DO (mg/l) shleter	DO change (mg/l)	Temperature °C river	Temperature °C shelter	pH shelter	Chlorine (mg/l) free residual	Chlorine (mg/l) total residual
8:30a.m.	7.80	7.7	-0.10	20.0	20.6			
8:45	7.85	7.8	-0.05	19.8	20.5			
9:00	7.95	7.8	-0.15	19.9	20.7			
9:15	8.05	8.0	-0.05	20.0	20.7			
9:30	8.25	8.2	-0.05	20.3	20.9			
		Average DO =	0.08					
10:00	Start Cl_2 cycle, rate = 3#/day, cycles/day = 3							
10:06						7.05	0.0	0.1
10:16						6.87	16.8	17.2
10:33						7.00	0.6	1.1
10:43						7.25	0.0	0.1
11:15	9.50	9.55	0.05		22.0			
11:30	9.65	9.60	-0.05		22.0			
11:45	9.85	9.75	-0.10		22.1			
12:00N	10.00	9.90	-0.10		22.2			
12:15	10.15	10.20	0.05		22.4			
		Average DO =	0.03					

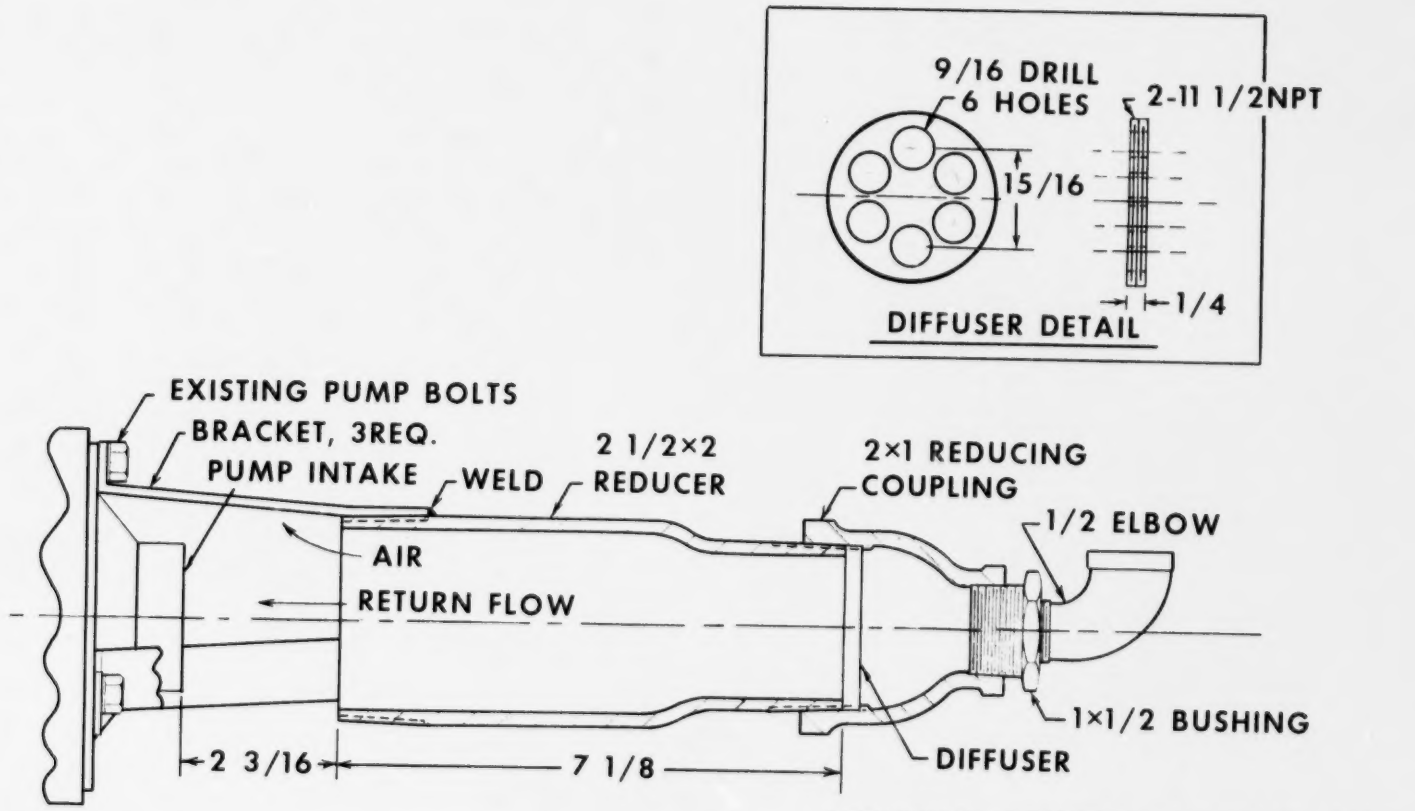

Figure 6. Air separator assembly

APPENDIX C

PARTS LIST
(SEE FIGURES 1, 2, AND 3)

These products were used mainly as a matter of convenience for evaluating the feasibility of automatic cleaning on small pumping systems. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

First Stage Pump	- Prosser Industries, Inc. Submersible Model 9-1312-4, 1 HP, Single phase, 230 V.
Second Stage Pump	- FMC Corporation, Peerless Dynaflo Submersible, Model 4D100B-15-1, Single phase, 230 V.
Flow Meter	- Aeroquip Corporation, Barco Div. a) Venturi Model 1 in. - 705, b) Portable Master Meter Model M-56, 0-50 in. of water differential.
V_1,V_2	- Wm. Powell Company a) Ball Valve "Star" 1-1/4in.* b) Electric Operator,* 115 V, 60 cy. Cat. No. 4256 *1 in. ball valve with smaller electric operator could have been used.
V_3	- Capital Controls Co., Inc. Plast-O-Matic Vacuum Shut off valve for Model 201 Gas Chlorination System. Solenoid operated.
G_1,G_2	- Marsh Instrument Company Pressure gauge type 1., 2-1/2 in. dial, dial range 60 lb.
G_3	- Marsh Instrument Company Pressure gauge type 1., 2-1/2 in. dial, dial range 30 lb.

G_4,G_5	- Marsh Instrument Company Gauge type 3, compound, 2-1/2 in. dial, dial range 30 in. x 30 lb.
Chlorination System	- Capital Controls Co., Inc. a) Gas chlorination system, Model 201 b) No. 15 nozzle, 0.56 in. orifice c) Metering tube, Model A 108 (4 lb/day).
Chlorine	- Will Ross, Inc., Matheson Gas Products Div. Cl_2 MW 70.906 cylinder size 5, 15 lb, 38 lb gross wt.
FCV (Flow Control Valve)	- Eaton Corporation, Dole Valve Div. a) 5 gpm b) 9 gpm.
Air Separator	- In-house design (Figure 6, Appendix B) Commercial air separators are also available.
Water Line Sizes	- a) Between first and second stage pumps-- 1-1/4 in. x 200 ft long flexible plastic pipe. b) Between second stage pump and G_1-- 1-1/2 in. x 300 ft long flexible plastic pipe.* c) Between G_1 and G_2--1-1/4 in. galvanized pipe. d) Between G_2 and G_3 (both directions)-- 1 in. galvanized pipe. e) Between V_1 and G_5 (both directions)-- 1 in. galvanized pipe with exception that ejector effluent tube is screwed into the center tap of a 1-1/2 in. galvanized tee. f) From G_5 and extending for 300 ft toward river--1-1/4 in. flexible plastic pipe.* *These lines could be reduced one size.
24 Hour Timer	- International Register Co. Intermatic Timer Model V37177 125 V, 60 Hz.
Cam Timer	- Singer Industrial Timer Corporation Industrial Timer Type RC 7, 4 switch chassis, single cycle with type A30 rear assembly.
Interval Timer	- Singer Industrial Timer Corporation Automatic Reset Delay/Interval Timer Model GP-30M, 115 VAC, 60 Hz.

Delay	-	American Machine and Foundry Co. Potter and Brumfield Div. Time Delay Relay, solid state, Model CKB-38-70010, Dwg. A. .1 to 10 sec. delay, 120 VAC.
Power Relay	-	American Machine and Foundry Company, Potter and Brumfield Div. General Purpose Relay, Type KRP5AG, 120 V, SPDT, 10 Amp.
Chlorine Shelter	-	Refer to Figure 3. Internal dimensions of shelter are 22 in. wide x 18 in. deep x 32 in. high. The shelter includes a large opening in front with double door and padlock. The walls and ceiling are insulated with 3-in. fiberglass insulation. The base of the shelter was mounted approximately 2-1/2 ft above ground level. The roof is gabled and covered with light gage metal. The entire unit is painted with an all weather enamel.